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CREATING NEW TECHNOLOGY BANDS FOR EMERGING TELECOMMUNICATIONS TECHNOLOGY

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FOR EMERGING
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EXECUTIVE SUMMARY

Recent advances in digital and signal processing systems have made possible the development of a broad range of new telecommunications services. Examples of these new services include personal communications systems, wireless computer networking, digital audio radio and mobile satellite services. The Commission's staff has conducted a study to examine the possibilities for making spectrum available for operation of new services made possible through emerging technologies. The findings of this study indicate that 220 MHz within the 1.85-2.20 GHz (2 GHz) band could be designated as "emerging technologies bands."

The study first identified the most likely candidate spectrum for the emerging technology bands. The goal was to find a relatively large amount of spectrum in the same frequency range that could technically support mobile operations with current state-of-the-art equipment. The upper limit for such operations was found to be 3 GHz. The study also found that there are no frequencies available below 1 GHz that could be made available to new services. Except for a few narrow bands, this spectrum is used for broadcast or mobile services that would be very difficult to relocate.

The study therefore focused on spectrum in the 1 to 3 GHz region. This area of the spectrum is also currently the subject of considerable technical research both domestically and internationally. The study concluded that the 1.85-2.20 MHz band, which is used by fixed service private and common carrier microwave systems, broadcast auxiliary facilities and MDS systems, was the most promising candidate for location of the emerging technology bands. The study found that the private and common carrier fixed service microwave systems in this band could be relocated to other, higher frequency fixed service microwave bands. Thus, the study found that the 220 MHz these systems now occupy could probably be made available for emerging technologies. The study further concluded that, under the current circumstances, it would be difficult to relocate the 2 GHz broadcast auxiliary and MDS operations, and consequently the frequencies they occupy should not be made part of the emerging technology bands at this time.

The study next examined the possibilities for relocating the existing 2 GHz fixed service microwave facilities to higher frequency fixed microwave bands or to alternative media, and the impact such relocation would have on the 2 GHz users. The search for higher frequency "relocation bands" was guided by the considerations that the technical characteristics of the existing operations in those bands must be compatible with the technical requirements of the 2 GHz services and that the relocation bands have sufficient remaining capacity to accommodate the 2 GHz users.

Three existing fixed microwave bands, those at 3.7-4.2 (4 GHz) GHz, 5.925-6.425 GHz (6 GHz), and 6.525-6.875 GHz (6 GHz), were identified as candidate relocation bands for the existing 2 GHz users. These bands can technically support the path lengths currently operated by the 2 GHz facilities and can provide comparably reliable service. The study also examined existing use of the 4 and 6 GHz bands to determine whether there is sufficient remaining capacity in these bands accommodate the 2 GHz users. This phase of the study examined the capacity in the 4 and 6 GHz bands on a nationwide basis and in the top 50 Metropolitan Statistical Areas (MSAs). The approach used in the analyses compared the sum of the existing 2, 4, and 6 GHz microwave facilities in a given geographic area with the sum of estimates of the capacities of the 4 and 6 GHz bands.

The nationwide analysis indicated that there is generally sufficient excess capacity in the 4 and 6 GHz bands across the entire country to accommodate the existing 2 GHz facilities. The analysis for the more densely concentrated MSAs also revealed that there is sufficient capacity to accommodate the 2 GHz facilities in all but three of the metropolitan areas studied. Further analysis indicates that any shortages of capacity in these areas could be accommodated through the use of fixed service microwave bands above 6 GHz. The study therefore concluded that the existing 2 GHz facilities can be reaccommodated with alternative spectrum nationwide.

The study also found that the use of alternative media, such as fiber optic cable and satellites, may offer a more attractive means of maintaining some of the services now provided on 2 GHz facilities. All major operators of 2 GHz fixed service users now employ fiber optics to some degree, and the current trend is toward more extensive use of this medium. The study also found, however, that microwave facilities continue to offer significant cost advantages over fiber in many cases. The study found that satellite facilities may offer a second alternative for fixed service users that require communications between many locations or locations that are relatively far apart.

Finally, the study examined the costs involved in relocating the 2 GHz facilities to higher frequencies. These costs will typically involve equipment and antenna replacement/upgrades and coordination of frequencies. Generally, because the 4 and 6 GHz bands can support the same path lengths currently operated by the 2 GHz facilities, 2 GHz licensees would not have to acquire additional transmit/receive sites. The study concluded that the economic considerations in converting from 2 GHz to frequencies above 3 GHz does not present a barrier to relocation.

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1.0 Introduction

1.1 Purpose. In recent years, technological advances in digital and signal processing systems have opened possibilities for the development of a broad range of new radio communications services. Examples of these new services include personal communications systems, wireless computer networking, digital audio radio and mobile satellite services. The upper frequency limit for commercial operation of the state-of-the-art light weight equipment these services will use is about 3 GHz. In order to provide spectrum for these and future emerging radio services, the Commission is considering the possibility of allocating spectrum under 3 GHz for use by new telecommunications services that employ emerging technologies. This approach is similar to that being pursued internationally. In particular, both Europe and Japan are now making new block allocations between 1 and 3 GHz for services that make use of emerging mobile technologies.

The United States has always been a leader in the use of the radio spectrum. Indeed, it is the intensive use of spectrum that now presents a challenge for the future. The very spectrum sought by the new technologies - the under 3 GHz, or "lower band" area of the spectrum is virtually all allocated to existing services. The spectrum reserve the Commission previously established at 800-900 MHz has been almost fully allocated for specific services. In order to make frequencies available for a "emerging technologies bands" and preserve the operation of existing services, it will be necessary to provide for relocation of some existing lower band services to alternative media or higher frequencies.

This study examined the possibilities for establishing emerging technologies bands in frequencies under 3 GHz. It identified the most likely region of this spectrum, determined its existing users, explored alternatives for relocating those users to higher bands, and examined the costs of such relocation.

In developing the analysis plan, the study staff recognized that, because most of the spectrum under 3 GHz is now heavily used, the task of establishing emerging technologies bands would be very challenging. The plan for making spectrum available for new services will have to consider the impact on existing operations to a much greater extent than the earlier reserve. A simple "band clearing" policy will not work. The implementation plan will need to include specific provisions for minimizing the impact of relocation on existing services in the bands selected for emerging technologies. For example, the impact could perhaps be minimized by providing an extended transition period and allowing parties seeking to operate new services to negotiate with existing licensees for access to frequencies in the emerging technologies bands.

1.2 General Approach. The search for an emerging technologies frequency band was guided by several considerations. In order to satisfy future demands and to be able to plan spectrum use effectively, there is need for a significant amount of spectrum that is located in a single range of frequencies. The spectrum has to be technically suitable for mobile operations to insure the availability of reasonably priced equipment. It is also necessary to consider spectrum decisions being made internationally that could affect the competitiveness of U.S. manufacturers.

The study first eliminated from consideration frequencies below 1 GHz. The majority of these frequencies are already used for broadcast and mobile services that would be difficult to relocate. The remaining frequencies below 1 GHz are narrow, scattered bands that do not provide a sufficient block of spectrum for the emerging technologies bands. Frequencies above 3 GHz were also eliminated from consideration, primarily because propagation characteristics in this area of the spectrum are less desirable for mobile operations. The study therefore focused on the 1 to 3 GHz band. Within this frequency band, the 1.85 to 2.20 GHz band became the most likely candidate for the emerging technologies bands. This band is technically suitable for the expected new mobile communications services. The current occupants of this band are fixed service point-to-point microwave (FS), broadcast auxiliary and multipoint distribution service (MDS) users.

The study used capacity analyses to determine the technical feasibility of relocating the existing 1.85 to 2.20 GHz operations to higher frequency bands and also examined the possibility of using alternative media such as fiber optics. The study finds that it may be difficult to move the broadcast auxiliary and MDS (wireless cable) licensees, at this time. The fixed service users, however, could be relocated to higher areas of the spectrum that are already being used for similar fixed operations. The study concludes that it is possible to make 220 MHz of spectrum available in the 1.85 to 2.20 GHz band for new services.

2.0 The Need for Emerging Technologies Bands

2.1 The Emerging Technologies Band Concept. Historically, the Commission has reserved spectrum for the development and growth of existing services. For example, in developing the FM radio service, the Commission reserved a block of channels for noncommercial educational use.[1] Similarly, the Commission has reserved certain television channels in each market for noncommercial educational use.[2] These "reserves" were established to ensure the availability of spectrum for the continued growth and expansion of noncommercial educational broadcast services.

In the early 1970s, the Commission took a different approach when it reallocated 115 MHz of the 806-960 MHz band to land mobile service in Docket No. 18262.[3]. This was one of largest and most significant reallocation actions undertaken by the Commission. This action made spectrum available to meet the growing needs of the land mobile industry. Of the 115 MHz, 40 MHz was allocated for the development of new "high capacity common carrier mobile communications systems," i.e., cellular radio, and 30 MHz was allocated for conventional and new trunked land mobile systems, including specialized mobile radio (SMR) services.[4] Most significantly during the course of this proceeding, a number of parties recommended the establishment of reserve bands to accommodate new land mobile services and unexpected growth in existing services. The Commission agreed with these recommendations and accordingly set aside 45 MHz of spectrum for a reserve. The reserve frequencies were not allocated to any specific use, but rather were designated simply as land mobile reserve.[5]

The spectrum reserve established in 1971 has proven the advantages of making a large block of spectrum available for new services. As envisioned, the 45 MHz has been used to introduce new services, foster new technology and provide for expansion of existing services. For instance, the reserve spectrum has been allocated for the new air-to-ground radio telephone service. Further, these frequencies have been used to introduce new technologies. The National Plan for public safety services on these frequencies will introduce new spectrum efficient technologies into the public safety radio services and cellular radio providers are now using these frequencies to introduce new advanced digital cellular concepts. Lastly, the reserve frequencies are being used by the cellular and land mobile community to meet expanded demand.

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[1] See 47 CFR Section 73.501. FM channel numbers 200 to 220 (87.9 to 91.9 MHz) are reserved for noncommercial educational service.

[2] See 47 CFR Section 73.606 (TV Table of Allotments).

[3] In many ways the actions taken by the Commission in establishing this allocation parallel our efforts today. In this regard, studies were undertaken to consider sharing and the impact on existing licensees. To make the spectrum available for land mobile in the 1970s, TV channels 70-83 (806-890 MHz) were reallocated. This required relocating two full service TV stations and approximately 600 TV translator stations to channels below 70. The remainder of the spectrum was obtained from government frequencies made available for non-government use.

[4] See Second Report and Order in Docket No. 18262, 46 FCC 2d 752 (1974).

[5] Id., at 759.

2.2 Domestic Developments. Recently, there have been an unprecedented number of requests for spectrum for new radio services and technologies, and for the expansion and growth of existing services. The Commission currently has before it several proposals for new personal communications services. These proposals include applications for advanced cordless telephones, wireless PBX systems, personal communications networks and advanced wireless data networks. In addition, the Commission has received more than 35 proposals under the new "pioneer's preference" policy for new services such as mobile satellite radio, "large" and "small" low earth orbit satellite systems (LEOS), digital audio broadcasting, and mobile data services. Future improvements in SMRs, cellular telephone, and public safety services, including advanced data capabilities, also are expected to need new spectrum.

2.3 International Developments. Similar new radio communications services and technologies are also emerging in other countries. Various forms of digital audio services are under development or being considered in Europe, Canada and Japan. These countries and Europe are also developing personal communications services (PCS). Some of the specific personal communications services currently being developed internationally include the British CT-2 advanced cordless telephone and CT-3 microcellular systems, Europe's general service mobile (GSM) system and Japan's "Handy Phone" service. In order to ensure the availability of spectrum for these services, the countries involved are allocating spectrum for new mobile services that use emerging technologies. For example, Europe and Japan recently have moved to allocate spectrum between 1 and 3 GHz for mobile services that use new technologies. In addition, the 1992 World Administrative Radio conference will address the allocation of spectrum for new mobile services.[6]

2.4 New Spectrum Needed. From the above it appears that the conditions that are present now with regard to the development of new communications systems are similar to those which led the Commission to reallocate frequencies for new services in the early 1970s. Several existing services are continuing to grow and develop and therefore need additional spectrum. Also, there are a number of promising new radio communications services on the horizon and there are no suitable large blocks of unallocated spectrum available for their operation. Further, spectrum is needed for development of future services. Thus, the Commission again needs to consider a reallocation plan to provide sufficient frequencies for growth of existing services, emerging services and to make spectrum available to be developed in the future. This reallocation is important not only to improve communications for the American public, but also to allow this country to maintain its competitive leadership in the international communications market.

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[6] The agenda for the 1992 WARC includes issues concerning allocations to accommodate new technologies and services in the 1 to 3 GHz band. These technologies include: broadcast satellite service (sound), mobile satellite service and associated feederlinks, world-wide development of public correspondence with aircraft (airborne telephone service), future public land mobile telephone systems and developmental space research. See Document 7048-E (CA45-142), ITU Administrative Council, June 21, 1990. Several administrations, as of October, 1991, have expressed interest in establishing non-fixed allocations in the 1 to 3 GHz band. These administrations include: Australia, Argentina, Austria, Belgium, Brazil, Canada, China, Czechoslovakia, Denmark, Finland, France, Germany, Hong Kong, Hungary, India, Indonesia, Ireland, Japan, Korea, Malaysia, Mexico, Netherlands, Norway, New Guinea, Philippines, Poland, Romania, Singapore, Spain, Sweden, Switzerland, Thailand, United Kingdom, USSR, Vietnam, and CEPT.

3.0 Identification of Candidate Bands

3.1 Desired Characteristics of Emerging Technologies Band. The initial task of the study was to determine which frequency bands are candidates for the emerging technologies bands. The selection of bands for new technologies is, of course, dependent upon the spectrum needs and propagation characteristics required by the new services envisioned. In addition, other factors should be considered:

- Cost of equipment. If the spectrum chosen is in a range for which state-of-the-art equipment is not imminently available, then high costs would delay introduction of new services.

- Amount of Spectrum. There must be enough spectrum available to allow substantial development and economies of scale.

- Feasibility of relocation. The existing licensees in the target spectrum must be relocatable to alternative media or other spectrum with a minimum of cost and disruption of service.

- Non-government spectrum. In order to avoid the need for coordination and to speed the process of transition, the emerging technologies band should come entirely from spectrum regulated by the FCC.

- International developments. It is desirable for the emerging technologies band to be compatible with similar international developments. The WARC-92 will most likely focus on this spectrum for mobile use.

3.2 Band Examination. The list of candidates for emerging technologies bands was initially narrowed based on the availability of electronic components and current manufacturing capabilities. While experimental mobile use is taking place at higher bands, the state-of-the-art technology for compact, light-weight, portable, electronic components is generally limited to frequencies below 3 GHz. Research is underway to increase this limit. However, there is no way to predict when the technology will be available. Thus, the study eliminated frequencies above 3 GHz from consideration. Major frequency bands below 3 GHz were also considered. The study determined that nearly all of the frequencies below 900 MHz are used for mobile or broadcast services and would pose very complex re-accommodation problems. The remainder of the frequency bands below 900 MHz offer only small, disjointed bands of spectrum that are not suited to the spectrum requirements of emerging technologies. The study, thus, focused on the 1 to 3 GHz band.

The study identified three non-government frequency bands as possible emerging technology band candidates in the 1 to 3 GHz region of the spectrum. These were: 1.85-2.20 GHz, 2.45-2.50 GHz and 2.50-2.69 GHz. Each of these bands was carefully examined and considered with regard to its suitability for use by emerging technologies. The 1.85-2.20 GHz band is currently used for fixed point-to-point microwave operations, broadcast auxiliary operations such as studio to transmitter links and mobile electronic news gathering, and some MDS which is often referred to as wireless cable.[7] The 2.45-2.50 GHz band is allocated for use by Industrial, Scientific, and Medical (ISM) equipment and broadcast auxiliary services.[8] The 2.50-2.69 GHz band is the primary MDS band.[9]

The study concludes that the 1.85-2.20 GHz band is the best candidate location for the emerging technologies bands. This band offers a large amount (350 MHz) of contiguous spectrum. Moreover, fixed operations similar to those in this band are supported currently in other frequency bands, making relocation to comparable service bands a possibility. The ISM frequency band, 2.45-2.50 GHz, was found to be a less desirable alternative because it has a limited amount of spectrum (50 MHz) and replacement bands are not available that provide the same physical characteristics for existing ISM operations.[10] The MDS frequency band, 2.50-2.69 GHz, was eliminated because there are no alternative frequency allocations currently available to support these operations. When all of the factors are considered, the 350 MHz of contiguous spectrum in the 1.85-2.20 GHz band emerges as the primary candidate for location of the emerging technologies bands.

3.3 Current Use of the Candidate Band. The study examined the current uses of the 1.85-2.20 GHz band. Comprehensive and detailed analyses were conducted to determine the number of licensees, the number of facilities or transmitters, the location of the facilities, the technical operating parameters of the facilities, and the communications requirements of existing licensees in this band. Figure 1 shows how the 1.85-2.20 GHz band is allocated currently by service:

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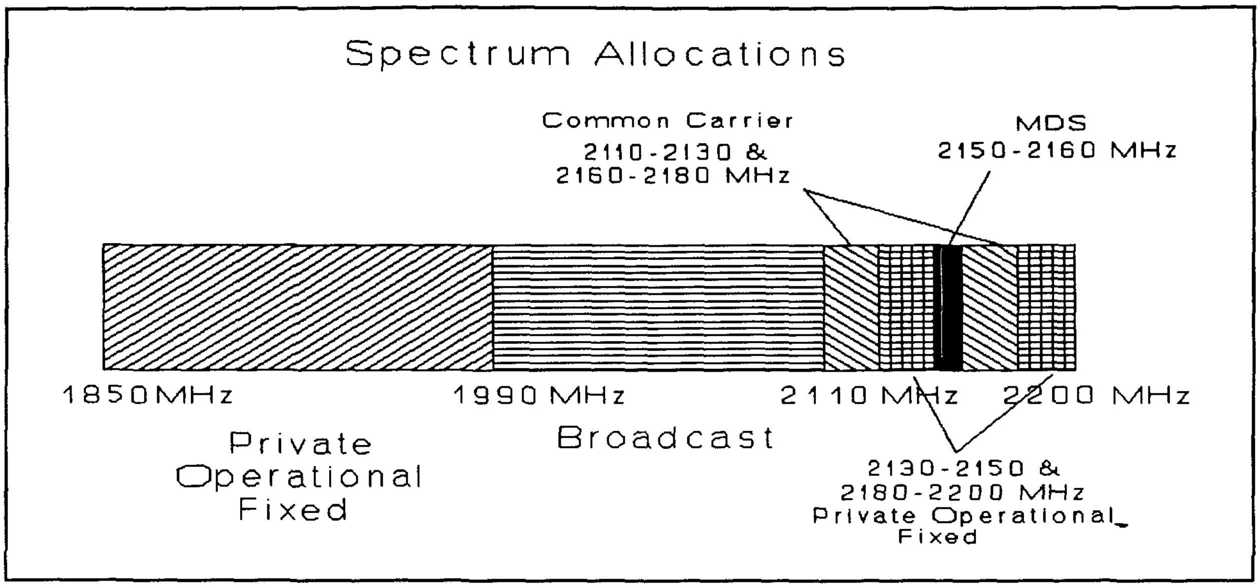
[7] See 47 CFR Parts 21, 74, 78, and 94.

[8] See 47 CFR Parts 18 and 74.

[9] See 47 CFR Parts 74 and 94.

[10] The band 2.45 - 2.5 GHz is allocated as a special-use band for Industrial, Scientific and Medical (ISM) equipment, and is regulated by Part 18 of the rules. Some typical applications of ISM equipment are the production of physical biological effects, or chemical effects such as heating, ionization of gases, mechanical vibrations, hair removal, and acceleration of charged particles. Examples of ISM equipment are industrial heat sealers and dryers (industrial microwave ovens). This band may also be used for non-licensed low-powered RF devices regulated by Part 15 of the rules. Examples of the non-licensed devices operating in this band are microwave ovens and field disturbance sensors (burglar alarms).

Figure 1



The Commission's XFS database was used as the primary informational source for the study.[11] Initial studies, however, revealed that the current XFS database might be unreliable in a number of areas. Several common carrier entities generously volunteered the use of their databases to both update and verify the records contained in the XFS database.[12] Computer programs were developed to analyze the database by various categories relevant to the project. Table 1 shows the number of licensees, the number of facilities and the principal types of operations for each of the five sub-bands.

[11] The FCC XFS data base is the central electronic repository of radio assignments licensed by the Commission. The records in this data base contain administrative (e.g., licensee names and call signs), and some engineering data, (e.g., geographical coordinates and operating frequencies).

[12] Information was obtained from AT&T, MCI, McCaw Cellular, Inc., and Bell Communications Research Laboratory. Comsearch supplied record counts for verifications.

TABLE 1: STATISTICAL DATA FOR 2 GHz BANDS

BAND	RADIO SERVICE	LICENSEES	FACILITIES	CHANNEL BW	AVG. PATH LENGTH	Types of Uses	Sample Licensees
1850-1990 MHz Private Radio Services	Local Gov't. including Public Safety	168	2011	5 MHz 10 MHz	19.8 miles	Fixed Point to Point Control, Voice & Data	LA Sheriff, State of Florida, City of Dallas
	Petroleum	67	2487				Shell, Chevron, Exxon
	Power	164	3197				Georgia Power, Dairyland Power Cooperative, Interstate Power
	Railroads	18	895				Union Pacific, Burlington Northern, Missouri Pacific
	Others	143	668				Citibank, Hewlett-Packard, Proctor and Gamble
1990-2110 MHz Broadcast Services	Broadcast Auxiliary	916	7359	17 MHz	30.4 miles (fixed)	Fixed and Mobile Broadcast Auxiliary - STL, ICR & ENG	ABC, CBS, NBC, Westinghouse
2110-2130/ 2160-2180 MHz Common Carrier Services	Telephone/ Cellular Paging	481	6823	3.5 MHz	17.9 miles	Fixed Point to Point Cellular cell tie ins & local telephone remote tie ins One-way Paging	Southwestern Bell, U.S West, McCaw, GTE
2130-2150/ 2180-2200 MHz Private Radio Services	Local Gov't. including Public Safety	549	4052	0.8 MHz 1.6 MHz	15.1 miles	Fixed Point to Point Control, Voice & Data	Commonwealth of Pennsylvania, State of California, Commonwealth of Virginia
	Petroleum	111	2933				Mobil, Amoco, Arco
	Power	258	3521				Pacific Gas and Electric, Southern California Edison, Allegheny Power
	Railroads	24	991				Atchison Topeka and Santa Fe Railway, CSX, Denver and Rio Grande Western
	Others	363	1538				Motorola, University of Maryland, Norstar bank
2150-2160 MHz Common Carrier Services	Multipoint Distribution	65	163	6 MHz	NA	Point to Multi-point Video Distribution (Wireless Cable)	Microband, Contemporary, Broadcast Data

As part of the study, a significant number of informal interviews were conducted with existing licensees, as well as with consultants, equipment manufacturers, and equipment vendors. The staff also met with representatives of Public Safety, Local Government, Petroleum, Railroads, Utilities, Cellular Service providers, Telephone Service providers, Broadcasters, Manufacturers, and Consultants. Site visits were conducted of communication facilities operated by utilities, petroleum, local government, public safety, broadcast, and cellular licensees. Interviews were held with all levels of the facilities' personnel. Additionally, information and maps concerning the operations of several microwave systems and broadcast auxiliary operations were considered in the study. This information enabled the study to develop an accurate picture of the types of facilities and uses that are presently in operation in the 1.85-2.20 GHz band. Specific information from these interviews is described below.

3.3.1 Private Radio Use. Private radio FS systems operate in three sub-bands within the 1.85-2.20 GHz band: the 1.85-1.99 GHz band, and the 2.13-2.15 GHz and the 2.18-2.20 GHz bands, which are available for paired operation. These bands are available for use by the following private radio services: 1) local government including public safety; 2) petroleum; 3) utilities; 4) railroads; and, 5) others including, but not limited to manufacturing, banking, and service industries.

The types of private systems that use these frequency bands have widely varying characteristics. Systems range from a few links between buildings to several hundred links.[13] Private fixed microwave systems are used to control electric power systems, oil and gas pipeline systems, backbone systems for public safety, and local government mobile communications systems.[14] Other uses of the band include routine business voice, data, and video traffic. Five and ten megahertz communications channel bandwidths are available in the 1.85-1.99 GHz band. Typical data throughputs support voice, high capacity data and video traffic. The 2.13-2.15 GHz band that is paired with the 2.18-2.20 GHz band is channelized into 800 kHz and 1.6 MHz channels. These bands support voice, data and slow scan video. The path length, or distance for operations in this band, range from less than one mile to over 100 miles. The average path length nationwide was determined to be 19.8 miles.

As similar private fixed microwave systems are also supported on higher frequency bands, the 1.85-1.99, 2.13-2.15 and 2.18-2.20 GHz bands appear to be potential candidates for the emerging technologies bands.

3.3.2 Broadcast Auxiliary Use. The 1.99-2.11 GHz band is allocated for fixed and mobile broadcast auxiliary use. Licensees in this band are broadcasters and cable operators. This band supports approximately 2000 fixed and 5500 mobile facilities. The fixed and mobile services in this band co-exist because of extensive coordination between licensees. Fixed microwave

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[13] The systems in these bands range from 2 links owned by entities such as Yakima City, Sussex Trust Bank, and Spring Ambulance Service to Georgia Power's 394, Burlington Railroad's 526, and Chevron's 556.

[14] For example, the Los Angeles Sheriff's Department employs this band extensively for the backbone of its mobile communications system. Utility, petroleum, and railroad operators use these frequencies to monitor and control their systems.

operations in this band are used for a variety of purposes, including to transmit programming between a studio and a transmitter (STL), to distribute programming over a state operated public television network (inner city relay), and to transmit programming from remote satellite receive sites to the transmitter. The path length of these microwave facilities range from less than one mile to 100 miles. The average path length for this service is 30.4 miles.

The mobile operations in the 1.99-2.11 GHz band are used primarily for electronic news gathering (ENG). Mobile units are typically vans that are equipped to feed live programming while parked at the location of a news event. These vans, which usually have 40 foot masts and highly directional antennas, establish a microwave path with the receive site. ENG facilities are also installed in airplanes and helicopters. These units use steerable antennas to relay live programming to the television station while in flight. ENG operations are usually confined to a TV station's coverage area and are used extensively to relay live programming from breaking news events such as accidents, fires, and natural disasters. According to the interviews with licensees, when a major news event occurs, the demand for ENG frequencies frequently exceeds the available 2 GHz capacity. At other times, however, ENG facilities may not be used for long periods of time.

The 6.875-7.125 GHz (7 GHz) broadcast auxiliary band was the only band identified as a candidate relocation band for the 1.99-2.11 GHz operations. The 7 GHz band is allocated for the same fixed and mobile broadcast services as the 1.99-2.11 GHz band and licensees make use of both bands as necessary. Licensees in an area often share sites for their fixed facilities and require real-time frequency coordination to relay video back to their stations using ENG vans. They indicate that the spectrum available now is only marginally adequate for their needs during news events and other periods of high demand. In these discussions, the licensees emphasize that heavy demands placed on the broadcast auxiliary spectrum during these times and that congestion often occurs. They anticipate that the introduction of HDTV will make the congestion even more severe.

The study finds that because of the introduction of ATV there is considerable uncertainty with regard to the demand for broadcast auxiliary services. As a result, the future requirements of the broadcast auxiliary services for operating spectrum are not known. In addition, it appears from the interviews with broadcast licensees, that the 25 MHz allocated for the broadcast auxiliary service at 7 GHz may not be adequate to support both fixed and mobile operations during major news events and other periods of heavy demand. Accordingly, the study concludes that it would not be desirable to consider relocating those services at this time.[15]

3.3.3 Common Carrier Use. The 2.11-2.13 GHz band is paired with the 2.16-2.18 GHz band, and both are allocated for common carrier fixed service use. These bands are occupied mostly by telephone and cellular telephone service providers. The 2.15-2.16 GHz band is allocated for multipoint distribution services (MDS).

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[15] We note, however, that industry groups are currently pursuing research into video digital compression systems. Several video compression systems have been demonstrated that can transmit two to four video signals within a single NTSC channel bandwidth. This technology may offer some potential for improving the spectrum efficiency of mobile ENG operations.

Telephone companies use the 2.11-2.13 and 2.16-2.18 GHz bands to supply telephone service to remote or sparsely populated areas, and to locations where installing telephone lines is not feasible. The cellular telephone providers employ fixed microwave facilities in this band as part of the network backbone to interconnect cell sites with the mobile telephone switching office. These bands are also used by the Improved Mobile Telephone Service (IMTS) for control and repeater functions. The path lengths vary from less than one mile to over 100 miles. The national average path length is 17.9 miles. As similar common carrier fixed microwave systems are also supported on higher frequency bands, the 2.11-2.13/2.16-2.18 GHz band appears to be a potential candidate for the new technologies band.

MDS operators use the 2.15-2.16 GHz band to supply video programming to subscribers over city-wide areas, and in some rural areas where it is not economical to install cable TV service. The primary frequencies allocated for MDS are located in the 2.596-2.644 GHz band.[16] In addition, two channels are available in the 2.15-2.16 GHz band.

A total of 163 MDS facilities, operated by 65 licensees, were identified as operating in the 2.15-2.16 GHz band. Because MDS provides video distribution over a wide geographical area, it is generally incompatible with fixed or mobile operations. Over 24,000 applications are currently on file with the Common Carrier Bureau. Additionally, the rules governing the MDS service now permit increased sharing between MDS and the instructional fixed television service (ITFS).[17] Further, MDS operations may also be affected significantly by the introduction of ATV. In light of the above, the study concluded that this band should not be considered as a potential candidate for an emerging technologies band at this time.

3.4 Summary of Findings. Based on our examination of licensee information utilization patterns and system design/construction practices, the 1.85-2.20 GHz band can be divided into three basic categories: general fixed service operation, broadcast auxiliary fixed and mobile use, and MDS. The study finds that the 220 MHz currently used for general fixed service operation appears to offer the best candidate for the emerging technologies bands. It further finds that relocation of broadcast auxiliary and MDS operations should not be pursued at this time. There is considerable uncertainty about the future needs for broadcast auxiliary spectrum and there are indications that the combined spectrum that is currently available for this service at 2 and 7 GHz is only marginally sufficient for current needs. MDS is still a developing service and a change in its allotted frequencies now could prove harmful to that development. Accordingly, the remainder of this report will focus only on the possible relocation of the 2 GHz fixed common carrier and private services.

[16] This band provides two sets of four 6 MHz channels for MDS use. There are 143 systems operated by 110 licensees identified in this band.

[17] ITFS stations are used by educational institutions to provide video services. The ITFS frequencies at 2.596 to 2.644 GHz are shared with MDS. Existing operators are permitted to lease unused channels to MDS operators. MDS operators are eligible to apply for unused ITFS spectrum to augment their MDS systems.

4.0 Technical Feasibility of Relocation

4.1 Introduction. The primary focus of the study is to evaluate the technical feasibility of relocating the current fixed microwave services operating in the 1.85-1.99 GHz, 2.11-2.15 GHz and 2.16-2.2 GHz to alternative media or spectrum above 3 GHz. This section of the study investigates the possibility of relocating existing 2 GHz facilities to other frequency bands. An examination of alternative media is provided in Section 5.0.

Determination of the technical feasibility of relocating the current 2 GHz fixed microwave facilities requires examination of two key issues. First, the technical requirements of the existing 2 GHz services must be compatible with the technical characteristics (such as, propagation and channel bandwidth) of microwave systems operating at the higher frequency bands. Second, there must be sufficient spectrum capacity available at these higher frequencies to accommodate the existing 2 GHz facilities.

All fixed microwave frequency bands above 2 GHz were examined. The analysis used computer studies, telephone interviews, meetings with industry representatives, and on-site visits.

4.2 General Approach and Methodology. The objective of this portion of the study was to estimate the technical feasibility of relocating the 2 GHz fixed microwave operations to higher frequency bands. The methodology and analyses used in the study were intended to provide only broad measures of relocation capacity and were not designed to provide a relocation scheme for specific individual facilities.

The first step was to determine the current operational requirements of the 2 GHz fixed microwave facilities. This information was then used to determine which of the frequency bands between 4 and 23 GHz that are now used for fixed microwave services could also technically support the operations of the 2 GHz services.[18] The primary considerations in this determination were whether the higher bands could readily support the types of fixed operations to be relocated and whether those bands could accommodate the path lengths currently being used by the 2 GHz facilities.[19]

Once the likely candidate relocation bands were identified, the next step was to perform general spectrum capacity analyses for these bands. The process to determine the availability of spectrum capacity involved several steps. First, the number of 2 GHz facilities to be relocated

[18] In order to narrow the focus of the study and minimize disruption in the potential relocation bands, only those bands that are already assigned to uses similar to those being relocated are considered. This approach is based on the observation that it is easier to intermix operations of the same basic operating requirements than to introduce a different type of operation into a mature band. For example, to attempt to introduce an FS into a predominately mobile allocation could cause disruption to both types of users.

[19] The specific aspects of individual facility operations, such as actual channel bandwidths, were not considered. However, the operational characteristics of the 4 and 6 GHz services are generally comparable to, or more extensive than, the operational characteristics of the 2 GHz band.

was determined by geographical areas. The capacity of the available relocation bands was then estimated for the same geographical areas. These estimates were used as "benchmarks" for the capacity available in each of the relocation bands.[20] For each geographical area, the number of actual facilities currently operating in each relocation band was subtracted from the benchmark for that band to estimate the available excess capacity that could be used to accommodate the 2 GHz users in that area.

Next, the number of facilities to be relocated was compared with the available excess capacity in each area to determine whether the available excess capacity was sufficient to accommodate the 2 GHz facilities in that area. The study used one degree square zones nationwide and two degree square zones centered on the top 50 metropolitan statistical areas for the geographical analyses. Details of these steps are more fully explained in the following sections.

4.3 Operational Requirements of 2 GHz Facilities. The current 2 GHz fixed microwave facilities provide many important and vital services to the U.S. public. Any relocation of these important operations to other communications frequencies or services must be made in a manner that ensures the minimum disruption to the existing licensees and to the public. In order to provide a comprehensive review of relocation alternatives, the study investigated alternative frequency bands, in particular, frequencies above 3 GHz, as well as, the use of alternative media, such as, fiber optic cable and satellites, which are discussed in Section 5.0.

The study used the following criteria to identify spectrum above 3 GHz that is suitable for relocation of the 2 GHz facilities: 1) the relocation spectrum must be in spectrum already allocated for fixed microwave operations; 2) the relocation spectrum must support the present technical requirements of the 2 GHz facilities to be relocated at reasonable cost; and 3) the relocation bands must have sufficient capacity to support the introduction of the additional 2 GHz facilities.

The table below lists the primary candidate relocation bands for the 2 GHz fixed services, the types of services currently operating in those bands and other general information.

[20] It should be noted that the use of the benchmarks as an indicator of available capacity may overstate or understate the actual capacity available in given areas. For example, differences in topography and routing of microwave systems may affect the availability of capacity. However, the benchmarks were estimated in such a manner that, for the purposes of this broad study, the available excess capacity estimates determined from the benchmarks are generally applicable nationwide.

TABLE 2: PRIMARY RELOCATION BAND CANDIDATES

FREQUENCY	SERVICE	CH WD	COORDINATION	USE	REMARKS
3700-4200 MHz	Common Carrier (21) (25)	20 MHz	150 Mi. radius	Fixed Microwave (Major Backbone) Fixed Satellite (S to E) TV STL (CC)	Non-protected Home TV dishes. No replacement service on other bands.
5925-6425 MHz	Common Carrier (21) (25)	30 MHz	150 Mi. radius	Fixed Microwave (Major Backbone) Fixed Satellite (E to S) TV STL (CC)	
6425-6525 MHz	B/C Auxiliary (74) Cable TV (78) Common Carrier(21) Private Radio (94)	1 MHz 8 MHz 25 MHz	Locally coordinated temporary mobile use.	Fixed STL, Intercity Relay and Mobile ENG CC Local TV Service (Mobile, ENG)	Possible relocation for B/C Fixed.
6525-6875 MHz	Private Radio (94)	0.8 MHz 1.6 MHz 5.0 MHz 10. MHz	150 Mi. radius	Fixed Microwave Fixed Satellite	
6875-7125 MHz	B/C Auxiliary (74) Cable TV (78) Common Carrier(21)	25 MHz	Locally coordinated temporary mobile use.	Mobile TV Pickup Only Common Carrier Local TV Transmission Service	
10.7-11.7 GHz	Common Carrier(21)	40 MHz	150 Mi. radius	Fixed Microwave International Satellite	Used as overflow from 4 & 6 GHz. Expensive equipment, BW too wide, 240, 4 kHz chs min.
11.7-12.2 GHz	Common Carrier (21) (25)	case by case	Locally coordinated temporary mobile use.	Satellite (S to E) Local TV Transmission Service	
12.7-13.25 GHz	B/C Auxiliary (74) Cable TV (78) Common Carrier (21) Private Radio (94)	6 MHz 25 MHz		Cable TV Relay Service (CARS) Satellite (E to S) Local TV Service	
17.7-19.7 GHz	B/C Auxiliary (74) Cable TV (78) Common Carrier(21) Private Radio (94)	2 MHz 5 MHz 6 MHz 10 MHz 20 MHz 80 MHz 220 MHz	15-150 Mi. radius depending on service coordinator.	STL, TV Relay, TV Translator Relay CARS Space to Earth Point to Point Point to Multi-Point	Short haul lightly used.

4.3.1 Availability and Cost. Interviews with licensees indicate that communications availability and cost are the most important concerns with regard to microwave operations.[21] The principal technical consideration for availability and cost is the path length of the microwave link.[22] In order to maintain the same level of communications availability while minimizing cost, any relocation band would need to be able to support communications over distances equal to path lengths of the existing 2 GHz facilities. This would minimize the need for construction of additional relay "hops," thereby greatly reducing the impact of the relocation. The average path lengths of the existing 2 GHz FS operations, which were determined from the augmented XFS database, are:

Frequency Band	Avg. Path Length
1.85-1.99 GHz	20 miles
2.11-2.13 / 2.16-2.18 GHz	18 miles
2.13-2.15 / 2.18-2.20 GHz	15 miles

4.3.2 Path Length. Fixed microwave systems are generally limited to line-of-sight transmissions. As a rule of thumb, for the same quality of service, the path length over which a microwave system can reliably operate is inversely proportional to frequency, i.e., as frequency increases, the usable path length becomes shorter. The issue then becomes whether the path lengths of the current 2 GHz operations can be supported at higher frequency bands.

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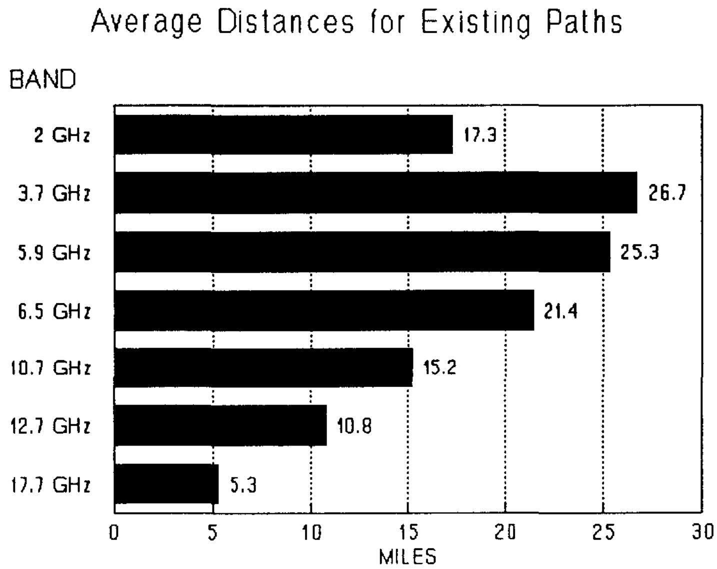
[21] Microwave system reliability is primarily a function of propagation conditions. Reliability is generally measured as the percentage of time the communications system is functioning properly. For example, the system is said to have a reliability of 99.99 percent if communications are disrupted less than .01 percent of the time during a year. This is equivalent to 53 minutes or less of disrupted communications in a one year period. Microwave systems must be designed to overcome changes in propagation that are commonly referred to as "fades." Fades depend upon several propagation related factors, including climatic conditions, multipath effects and path length. These factors must be taken into consideration in designing a microwave system. Each link in the microwave system is generally designed to have extra signal strength or fade margin to overcome the effects of fading. This additional signal strength is often referred to as fade margin. (Bernhard E. Keiser, Broadband Coding, Modulation, and Transmission Engineering, Prentice Hall, Englewood Cliffs, New Jersey, 1989)

[22] A "path length" here is defined as the distance between the transmit and receive sites.

Figure 2



In general, we believe the primary relocation bands at 4 GHz and 6 GHz can support the path length requirements of the existing 2 GHz facilities. Microwave links at all frequencies are designed to compensate for signal fades caused by natural phenomena. The depth and rate of fading generally increases with increasing radio frequency and path length. For a typical 30-mile overland path in the United States, multipath attenuation would be equal to or less than 25.5 dB at 2 GHz, and about 30.5 dB at 6 GHz.[23] The higher frequency signal would also experience 10 dB more of free space loss. On the other hand, antenna gain typically improves substantially with increases in operating frequency. This occurs because the effective area of an antenna is proportional to the wavelength being used. The higher the frequency the shorter the wavelength. For example, using identical 8 foot parabolic antennas, a 6 GHz link will achieve about 19 dB greater antenna gain than a 2 GHz link.[24] The increased antenna gain tends to offset the increased fading that occurs at higher frequencies. At frequencies above 6 GHz, microwave systems experience greater free space loss than can be compensated for by increased antenna gain. As a result, the achievable path length in bands above 6 GHz decreases with increases in operating frequency in these bands.

Localized increases in multipath fading, or "ducting" is a common occurrence along the coast of Southern California and the Gulf of Mexico. The effects of ducting are usually limited to locations over water and up to 30 miles inland. In these areas both the rate and depth of multipath fading increases. Paths over seawater experience especially severe fading due to

[23] "Propagation Data and Prediction Methods Required for Terrestrial Line-of-Sight Systems" CCIR Report 338-6, Reports of the CCIR, 1990.

[24] Richard C. Johnson and Henry Jasik, Antenna Engineering Handbook, 2d edition, McGraw Hill Book Co., 1984.

complete cancellation of the direct signal by reflections from the surface of the water. A 30 mile path over water could expect fade losses of 32 dB at 2 GHz, 38 dB at 4 GHz and 40 dB at 6 GHz for 99.99 percent of the year. Again, if identical antennas are used, the increased gain at the higher frequencies will more than compensate for the greater multipath losses.

Attenuation from the presence of rain also increases at higher frequencies. Rain attenuation to radio signals can be a significant factor above 10 GHz[25]. At frequencies of 6 GHz and lower, however, the fade due to multipath loss is much higher than that of rain, so that the "fade margin" designed into a link is generally sufficient to compensate for the effects of rain as well.

A comparison of existing microwave operations indicates the balancing effects of the fading and antenna gain factors in microwave systems operating on frequencies up to 6 GHz. In this frequency range, there are essentially no differences in useable path lengths. For example, Houston, TX, because of its weather conditions and proximity to the Gulf of Mexico, is subject to severe microwave fading conditions. Path length data for 2 GHz, 4 GHz, and 6 GHz facilities located in a two degree block centered on Houston shows the longest path length in each band is: 39 miles for the combined 2 GHz band; 33 miles for the 4 GHz; 34 for the 6 GHz common carrier band; and 44 for the 6 GHz private band. The median path length for each is: 15 miles for the 2 GHz band; 27 miles for the 4 GHz band; 22 miles for the 6 GHz common carrier band; and 20 miles for the 6 private band. These figures reveal that microwave operators in Houston have used the 4 GHz and 6 GHz bands as effectively as the 2 GHz band for their communications needs despite some of the worst fading conditions. Figure 2 shows the average path length achieved at 2 GHz compared with those achieved at higher frequency bands. These path length comparisons illustrate the ability of the relocation bands to support the path length requirements of the 2 GHz facilities as predicted by the engineering analysis.

This path length analysis found that 90% of all 2 GHz paths are less than 35 miles long and that the average 2 GHz path length is about 17 miles. Similar path length distances are found in the 4 GHz and 6 GHz Common Carrier bands and the 6 GHz Private band. As expected, the average path lengths for 10, 12 and 18 GHz systems are shorter, about 15, 10 and 5 miles, respectively.

Based on this information, the three most promising candidate relocation bands are the 3.7-4.2 GHz (4 GHz) and 5.925-6.425 GHz (6 GHz) common carrier bands, and the 6.525-6.825 GHz (6 GHz) private radio bands.[26] These bands are the closest in frequency to the 2 GHz bands; and, therefore, increased costs for new equipment, such as transmitters, receivers, and antennas,

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[26] Roger L. Freeman, Radio Systems Design for Telecommunications, John Wiley and Sons, 1987.

[26] Satellite and FS facilities are co-primary in each of these bands. The 3.7-4.2 GHz band is designated as a space-to-earth band where receive only earth stations operate. The majority of home TV satellite receivers operate in this band. The 5.925-6.425 GHz band is designated as a earth to space band or satellite up link.

should be minimized.[27] The 4 and 6 GHz bands are able to support path lengths at equal or greater distances than those being used by 2 GHz facilities.[28] For example, the average path lengths for the 2, 4 and 6 GHz bands are:

Frequency Band	Path Length
1.850 to 2.200 GHz	17 miles
3.700 to 4.200 GHz	27 miles
5.925 to 6.425 GHz	25 miles
6.525 to 6.875 GHz	21 miles

In summary, it appears that the 4 and 6 GHz bands can in most cases accommodate the path lengths operated in the 2 GHz bands. Other bands may also be able to accommodate some of the shorter 2 GHz links.

4.4 Spectrum Capacity Analysis. As indicated above, the study identified the 4 and 6 GHz bands as the principal candidate bands for relocating the existing 2 GHz operations. This section of the study investigates whether these bands have sufficient capacity to support the introduction of the additional 2 GHz facilities.

The feasibility of relocating facilities from one frequency band to another is depends on: 1) the number of facilities to be relocated; 2) the location of those facilities; and 3) the capacity available in the relocation spectrum at that location.

4.4.1 Distribution of 2 GHz Facilities. The first step in the capacity analysis was to determine the distribution of all existing users in the 2 GHz bands. A total of 29,116 fixed microwave facilities were identified in the 2 GHz private and common carrier bands, as shown in the table below:

[27] Cost of equipment in the 4 and 6 GHz bands is similar to the cost of 2 GHz equipment. Available equipment for the higher frequency bands is generally more expensive.

[28] In fact, as can be seen from above, the existing 4 and 6 GHz bands are currently used on the average for longer path length distances than the existing 2 GHz operations.

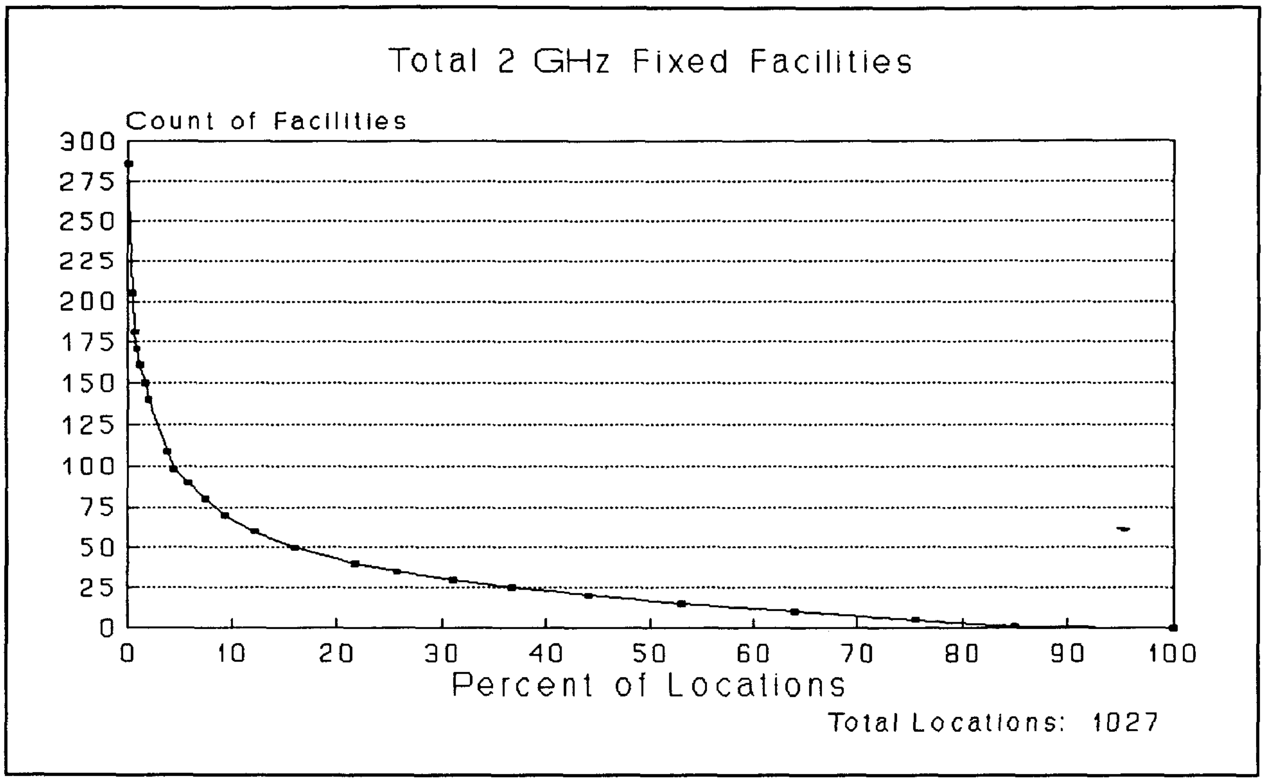
Table 3: 2 GHz Fixed Service Microwave Bands

BAND	LICENSING BUREAU	FACILITIES
1850-1990 MHz	PRB	9258
2110-2130 MHz paired with 2160-2180 MHz AT&T Data	CCB	6823
2130-2150 MHz paired with 2180-2200 MHz	PRB	13035
		TOTAL: 29116

A grid analysis was used to describe the distribution of fixed microwave facilities across the country. The analysis divided the country into individual one degree zones, or blocks, and counted the number of transmitters contained in each one degree zone.[29] As would be expected, the analysis shows that 2 GHz microwave facilities are not evenly distributed. Microwave concentration tends to be heavy in a few locations (blocks) due to specific industry needs. For example, the most congested zones for the 2 GHz band occur in Los Angeles, CA, Houston, TX and the petroleum pipeline corridor between Houston, TX and New Orleans, LA. However, the density of 2 GHz microwave facilities in the vast majority of the country is only moderate to light. Figures 3 and 4 show the distribution of facility densities for all the 2 GHz facilities.

[29] A grid analysis was used to obtain counts of facilities by geographical locations. A one-by-one degree block was chosen as the basic geographical area. This permitted existing map grids to be used for geographical reference and provided accurate information for associating the blocks with areas of interest for further study. A one degree block is approximately 60 miles on a side or an area of roughly 3600 square miles. As a result of the convergence of longitudinal lines, the blocks are not perfectly square. However, they are close enough in size for comparison purposes. The grid analysis used 1,027 to cover the contiguous 48 states and nearby areas such as the offshore area in the Gulf of Mexico. We recognize that FS systems are generally used for two-way communications and that an individual system may have transmitters located in different blocks. Nevertheless, for the purposes of this broad study, we believe counting transmitters within a zone is a reasonable approach for describing the distribution of fixed microwave facilities.

Figure 3



Total 2 GHz Fixed Facilities
Count of Facilities
300
275
250
225
200
175
150
125
100
75
50
25
0
0
10
20
30
40
50
60
70
80
90
100
Percent of Locations
Total Locations: 1027